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Research Article

Vehicle Detection And Vehicle Tracking Applications On Traffic Video Surveillance Systems: A systematic literature review

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Abstract:

The number of vehicles in traffic and the use of traffic surveillance systems are increasing day by day. This situation has revealed the necessity of control and analysis processes on traffic surveillance systems. Vehicle detection and vehicle tracking studies for the purpose of analyzing video sequences obtained from surveillance systems have recently become a popular field of study. Despite the increase in studies in this field, the aimed level has not been reached. Many reasons such as weather changes, day-night difference, vehicles blocking each other in traffic, background complexity make vehicle detection and tracking difficult. This study is presented to guide researchers who want to work in the field. In order to determine the common trends of the studies and to analyze the studies, a data set was created by searching the Web of Science database using the keywords "vehicle detection" and "vehicle tracking". In order to analyze the obtained data, the Voswiever (version 1.6.20) program and the R studio programs "bibliometrix" package and the biblioshiny application were used.

1. Introduction

Today, the increasing number of vehicles and developing roads have led to an increase in traffic chaos. Controlling and regulating the heavy traffic flow worldwide has emerged as the biggest problem of countries [1]. Traffic surveillance systems are used to prevent transportation problems and provide traffic analysis. Vehicle detection and tracking play an important role in traffic surveillance systems where traffic safety and management is considered as the main problem. Traffic surveillance systems are widely used for accidents, parking lot management, suspicious vehicle tracking, and vehicle theft [2].

The increasing interest in traffic management activities has been based on the acceleration of computer vision studies. Automatic object detection studies are carried out with the help of computer vision applications on video images obtained from traffic cameras installed on road networks. Images obtained from traffic surveillance systems are inspected and analyzed in real time or offline [3].

Traffic vehicle detection and tracking has become a popular research topic in recent years. Despite this, there are still many unsolved problems. This situation causes it to be an interesting field of study [4]. Many problems such as color and shape similarities of vehicles, their occluding each other, background complexity, light changes, weather conditions, wear of the cameras used in the outdoor environment and inability to obtain quality images are among the factors that make vehicle detection and tracking difficult [5].

Video-based camera surveillance systems use many different methods for object detection. The methods used for object tracking are based on the background subtraction technique. Faster Regional based Convolutional Neural Network (Faster R-CNN) and You Only Look Once (YOLO), which are deep learning models, are the prominent algorithms for object detection today [6]. Vehicle detection is accepted as the process of recognizing and localizing the types of objects on video frames. In this field where object detection algorithms are used, traditional machine learning methods and deep learning models stand out. In all algorithms used, determining the best representative features of the target object requires extensive knowledge and expert field knowledge. Since doing this process manually is a difficult process, deep learning methods that automate this process have replaced classical methods [7]. Vehicle tracking is the method used to redefine the objects detected on consecutive

frames in the video sequence and to associate the best matches. These methods use color, texture, shape and bounding box information to track objects. In addition to SIFT, SURF point-based tracking algorithms, Kalman or Particle Filter algorithms are also frequently used [8]. The aim of the study is to determine common trends in object detection and tracking studies on images obtained from traffic surveillance systems. It is possible to examine studies that solve the difficulties experienced in this field and to determine common approaches. It is aimed to provide a guiding literature analysis for researchers who want to conduct studies on vehicle detection and tracking.

The contents obtained from the Web of Science database were examined within the framework of the following questions:

- What is the distribution of the studies indexed in the Web of Science database in the field of vehicle detection and tracking according to categories?
- What is the distribution of the studies indexed in the Web of Science database in the field of vehicle detection and vehicle tracking by year?
- Which are the first authors of the studies indexed in the Web of Science database in the field of vehicle detection and vehicle tracking and how are the links between them?
- What are the keywords used in the studies indexed in the Web of Science database in the field of vehicle detection and vehicle tracking and how are the links between them?
- What is the distribution of the studies indexed in the Web of Science database in the field of vehicle detection and vehicle tracking by country and what is the strength of the links between these countries?
- What is the distribution of the studies indexed in the Web of Science database in the field of vehicle detection and vehicle tracking according to the most cited publications and what is the strength of the links between these publications?

The remainder of this paper is organized as follows: Section II describes recent related work in this field. Section III describes the research methodology used. Section IV presents the results and limitations of the research.

2. Related Works

There have been many studies in the field of vehicle detection and vehicle tracking in recent years. Some of the recent studies in these areas are presented below.

Wang (2020), in his study, addressed the difficulties experienced in vehicle detection and tracking and presented a new algorithm to solve the problem. In the study where traditional detection and tracking methods were examined, a detection algorithm for moving vehicles was proposed. In the study where vehicle detection was performed using background subtraction and correlation filtering methods, a solution was proposed for regional background complexity. It was argued that the proposed new algorithm is suitable for vehicle detection and tracking in environments with complex background scenes [9].

Hwang et al. (2009), proposed a stereo vision-based multiple vehicle detection system that aims to detect vehicles with higher accuracy rates in their studies. The proposed system uses morphological filter, feature detector and template matching techniques to detect vehicles. It was stated that this system performs the detection process regardless of whether the vehicle is in the front, back or side. The location parameters in the detection of vehicles were obtained using detection information [10].

Chong et al. (2013), proposed a real-time vehicle detection system. The system, which consists of vehicle detection and tracking stages, uses vehicle shadow features to create a region of interest (ROI). The location of the vehicle is determined with histogram equalization and edge extraction methods. In vehicle tracking, the bounding box is estimated and updated in each frame. During tracking, parameters such as distance, speed, number and type of vehicles are also determined. It is stated that the proposed algorithm has high detection rates [11].

Ashraf et al. (2023), proposed an image-based vehicle speed monitoring system consisting of vehicle detection, tracking and speed detection stages in smart traffic surveillance systems on highways. It is aimed to minimize the difficulties experienced in vehicle detection and increase detection accuracy with the help of an CNN-based hybrid vehicle detection network. Kalman filter is used for vehicle estimation and Hungarian Algorithm is used to solve the relationship problem between multiple vehicles. It is stated that the study performed vehicle detection with an accuracy rate of 87.242% [12].

3. Material and Methods

The aim of the study is to present a bibliometric analysis of studies conducted in the field of vehicle detection and vehicle tracking in the light of different parameters. Bibliometrics is defined as conducting a quantitative analysis examining the current status, development and distribution of information of relevant publications in the field studied. The aim is to determine the trends in the studies using this analysis [13, 14]. Bibliometric analysis is the method used to perform mathematical and statistical analysis of publications in the literature. Studies provide analysis opportunities

from many different parameter types such as citation, document type, subject or country [15].

3.1.Dataset

Within the scope of the study, bibliometric analysis studies were conducted on the contents indexed in the Web of Science database. In the search made in the database on "11.11.2024", the keywords "vehicle detection" and "vehicle tracking" were used. In the search made using the AND conjunction, all fields in the Web of Science database were selected. 405 publications were reached in the search made in the Web of Science database. It was determined that there were many different categories of studies between 1997 and 2025 according to the years. In the created dataset, the words with the same meaning, similar meanings and abbreviations were combined. For example, since the word "vehicle detection and tracking" was also detected separately in the keywords, it was combined with other data. The obtained findings were visualized in tables and graphics. The data belonging to the publication types obtained from the database are shown in Table 1.

Table 1. *Document types and numbers*

Document Types	Count
Proceedings Paper	211
Article	199
Early Access	6
Review	2
Book Chapter	1
Retracted Publication	1

The languages used in the studies were English (403) and Chinese (2). For the purpose of bibliometric analysis carried out on the studies obtained from the Web of Science database and using the keywords "vehicle detection" and "vehicle tracking" together, the Voswiever (version 1.6.20) program and the R studio programs "bibliometrix" package and "biblioshiny application" were used.

4. Findings

The study aimed to find answers to the research questions mentioned above. For this reason, the Web of Science database was examined on vehicle detection and vehicle tracking. Bibliometric analysis methods were applied to the indexed studies. The categories of data obtained from the Web of Science database within the scope of the study are given in Table 2. Table 2 shows the top ten categories among the studies conducted on vehicle detection and vehicle tracking. Apart from these categories, it was determined that studies were conducted in the

Table 2. *Numbers and percentages of publications in Web of Science categories*

Web of Science Categories	Count	%
Engineering Electrical Electronic	172	42.469
Computer Science Artificial Intelligence	118	29.136
Computer Science Theory Methods	73	18.025
Transportation Science Technology	72	17.778
Computer Science Information Systems	57	14.074
Imaging Science Photographic Technology	46	11.358
Engineering Civil	39	9.630
Telecommunications	36	8.889
Automation Control Systems	35	8.642
Computer Science Interdisciplinary Applications	25	6.173

categories of Optics, Robotics, Chemistry and Physics. It was observed that the studies were concentrated in the categories of Electrical Electronics and Computer Sciences. General information about the data obtained as a result of bibliometric analysis in 405 studies from which data was taken is given in Table 3.

Table 3. *Main information about the data obtained from the database*

Timespan	1997:2025
Sources (Journals, Books, etc)	293
Documents	405
Annual Growth Rate %	0
Document Average Age	7.6
Average citations per doc	18.66
References	8327
Keywords Plus (ID)	170
Author's Keywords (DE)	1042
Authors	1185
Authors of single-authored docs	15
Single-authored docs	17
Co-Authors per Doc	3.66
International co-authorships %	18.02

Table 3 shows that the data of 405 publications between 1997 and 2025 was examined. It is seen that the 405 published publications are included in 293 different sources. The total references of the publications were determined as 8327. The average number of citations per publication was 18.66, while the publication age was determined as 7.6. Other data obtained from the table include that 15 of these publications were single-authored and the co-authorship rate was 18.02%. The findings obtained from the bibliometric analysis applied on the data set are analyzed in terms of distribution and link strength according to publication years, fields, countries, most used keywords, number of author

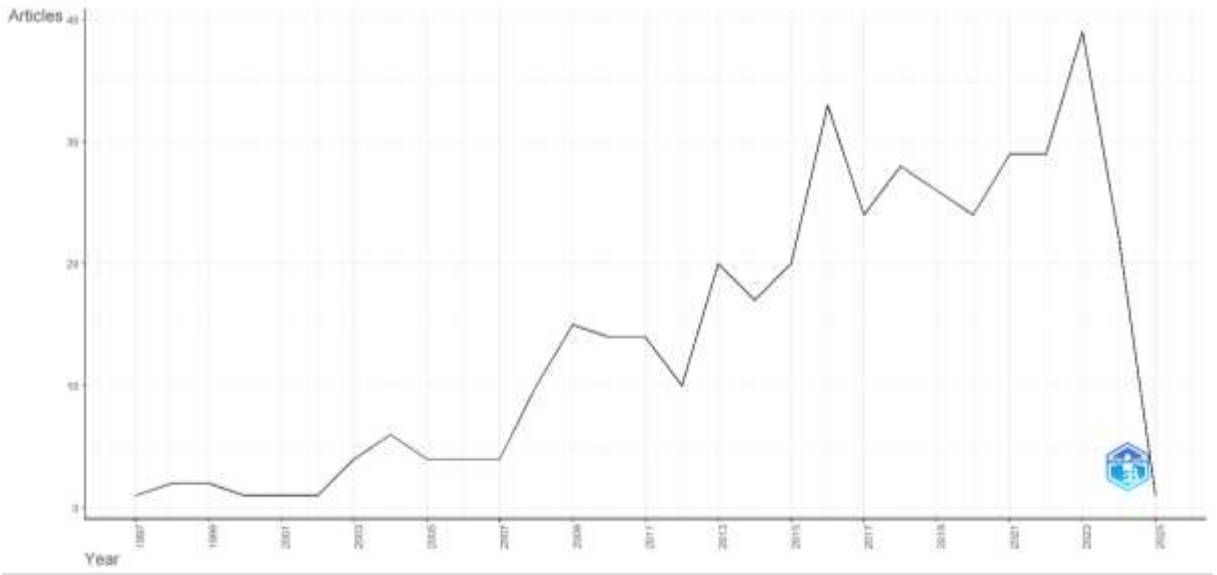

Figure 1. *Distribution of publications obtained from the dataset by year*

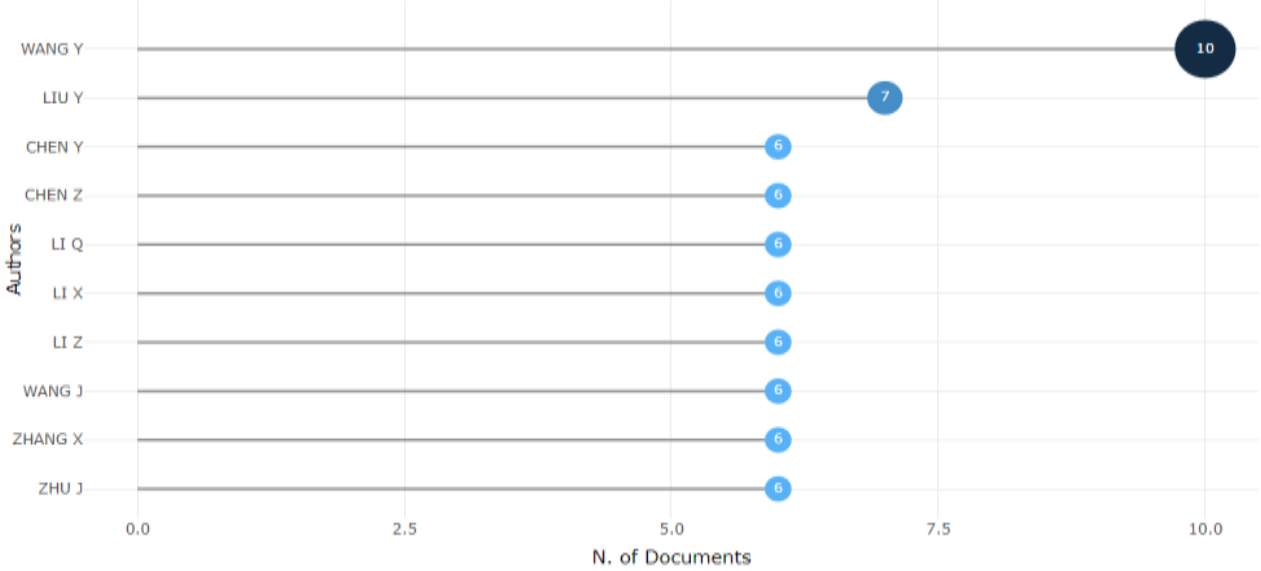

Figure 2. *The most relevant authors identified in the dataset and the number of publications they produced.*

citations and number of publication citations. Within the scope of the study, the first area analyzed was the distribution according to publication years. The publications in the field of vehicle detection and vehicle tracking in the Web of Science database were made between 1997 and 2025. The highest number of 36 publications was reached in 2023. Figure 1 shows the distribution of publications by years. When the distribution of publications by year is examined, it is seen that very little work was done in the field between 1997 and 2007. Total of 30 studies were conducted between these years when only single number of publications were made. It is observed that the studies gainedrapid momentum after 2013 and the highest number of publications was reached in 2023. The findings that emerged as a result of the application of bibliometric analysis on the data obtained from the Web of Science database are given under the following subheadings.

4.1. Author Profile and Analysis

A total of 1185 authors' works were obtained in the dataset obtained from the Web of Science database between the years 1997 and 2025, when publications were influential. The 5 most influential authors who have works in the fields of vehicle detection and vehicle tracking over the years were Yue Wang (10), Yuqiang Liu (7), Yajun Chen (6), Zhenzhong Chen (6), Qingquan Li (6), respectively. Figure 2, shows most relevant authors. The most cited authors are Anna Petrovskaya (8 citations), Sebastian Thrun (8 citations), Jahongir Azimjonov (7 citations), Ahmet Özmen (7 citations), and Mark Lee (4 citations) in the top five. When we look at the productivity status of the authors over the years, we see that the

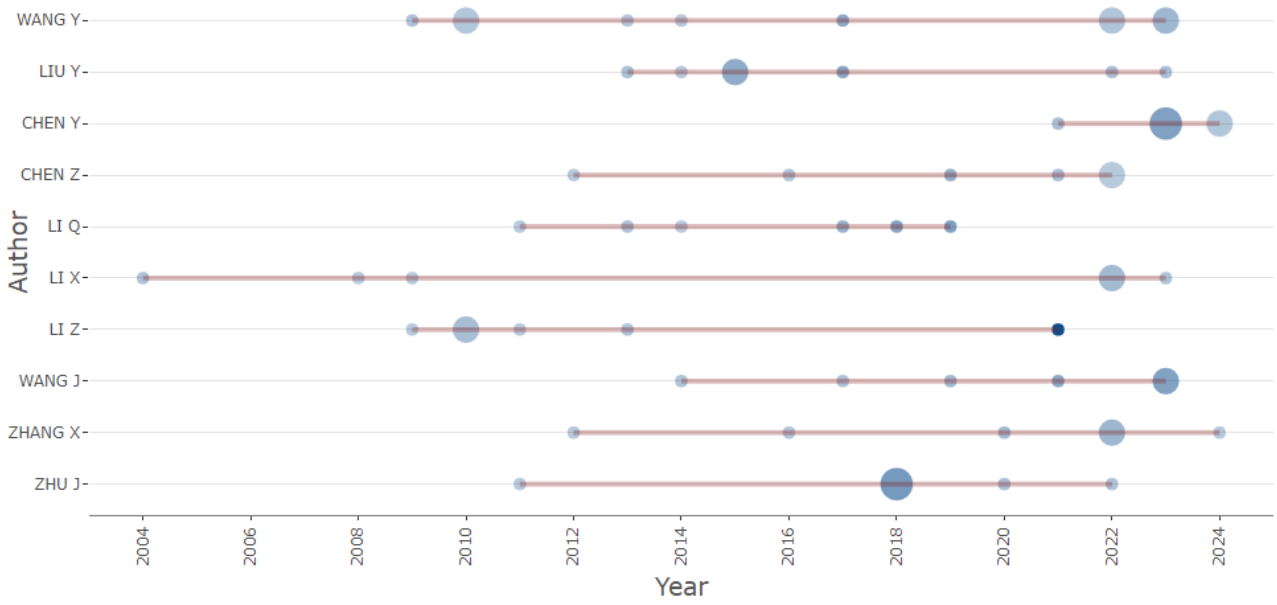

Figure 3. *Authors' productivity status by year*

prominent authors between 2013 and 2025, when the intensity of the studies increased, are Yue Wang, Yuqiang Liu, Yajun Chen, Yuqiang Liu, and Zhibin Li. Figure 3 shows the productivity analysis of the authors by year according to the bibliometric analysis findings obtained from the data set.

4.2 Keyword Analysis

The most frequently used keywords by authors in publications containing vehicle detection and vehicle tracking terms were analyzed. They were evaluated within the scope of the criterion of being used at least 5 times. Vehicle tracking with 187 repetitions, vehicle detection with 182 repetitions, deep learning with 25 repetitions, computer vision with 25 repetitions, and object detection with 21 repetitions are the most frequently used keywords. When analyzed in terms of the strength of the connection between them, it was determined that the first five most commonly used words were again vehicle tracking, vehicle detection, deep learning, computer vision, and object detection. YOLO, background subtraction, kalman filter, and convolutional neural network, which are among the common methods used in studies conducted in the field, can be counted as other prominent keywords. Figure 4 shows the network map of the change in author keywords in the publications in the data set over the years. In the studies obtained from the Web of Science database, the first five words in the visualization of the most frequently used words in the word cloud format are seen to be tracking, vehicle detection, classification, road and segmentation. Figure 5 shows the word cloud obtained from the most frequently used words and prepared by the R-Studio program.

4.3. Analysis of Countries

It was determined that the data obtained from the Web of Science database included publications from 53 countries. Bibliometric analysis was applied to 20 countries that passed the threshold value by meeting the minimum of 5 publications and 1 citation requirement. Table 4 shows the data for the top 15 countries in terms of the number of publications, citations and total link strength.

Table 4. *Number of publications, number of citations and total link strength of countries*

Country	Documents	Citations	Total Link Strength
China	133	1698	12553
USA	72	3530	8129
South Korea	32	248	2811
India	31	185	2444
England	14	671	2097
Taiwan	17	290	1839
Canada	9	171	1708
Spain	17	402	1498
Australia	7	55	1489
Germany	14	554	1480
Saudi Arabia	9	38	1429
Pakistan	8	67	1136
Turkey	7	108	833
France	5	237	833
Malaysia	6	26	798

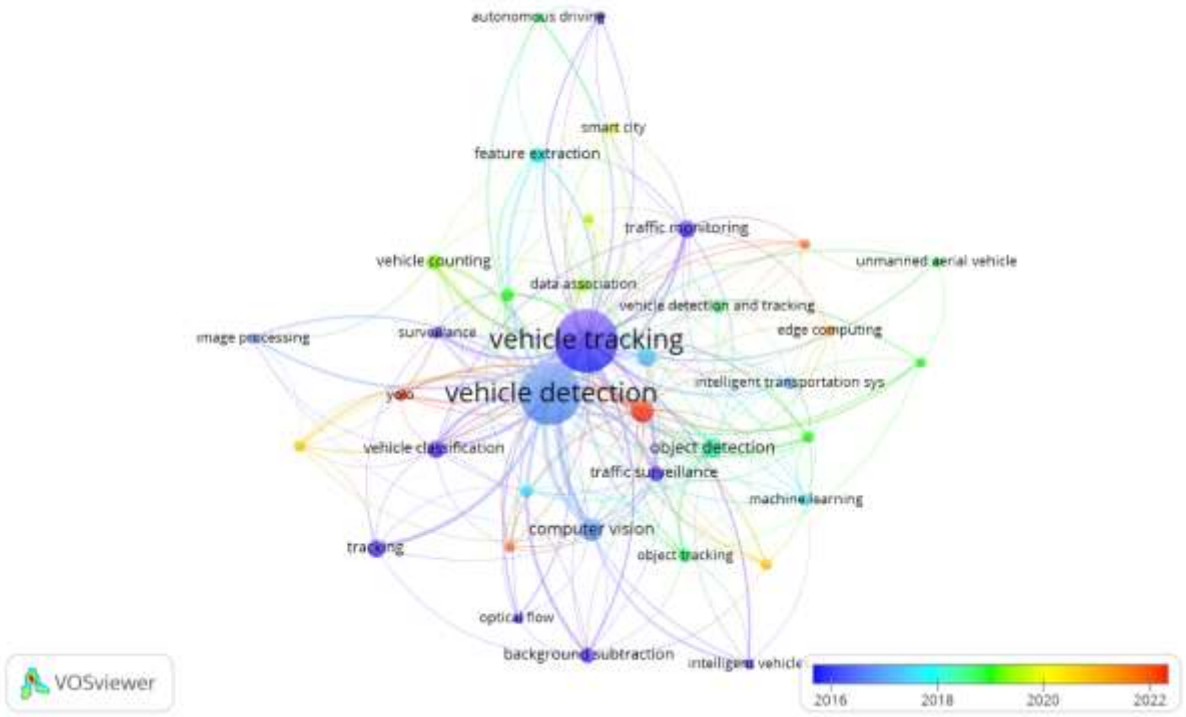

Figure 4. *Change analysis of the most frequently used keywords in the dataset over the years.*

Figure 5. *Word cloud obtained from the dataset.*

As a result of the bibliometric analysis, it was determined that the countries with the most publications were China (133), USA (72), South Korea (32), India (31) and England (14), respectively. The first five countries with the most citations were USA (3350 citations), China (1698 citations), England (671 citations), Germany (554 citations) and Spain (1498 citations). The first five countries that stand out in terms of total link strength are China, USA, South Korea, India and England. Figure 6 presents the network analysis showing the bibliographic matching of countries.

4.4. Citation analysis

The citation analysis on the dataset obtained from the Web of Science database was examined in two categories, namely publication and source. In order to conduct publication citation analysis, the criterion of having at least 1 publication was sought and 324 publications out of 405 passed the threshold value. Figure 7 shows the network map of the publications with the highest citations according to the findings obtained from the dataset. Another analysis most frequently used in studies is the analysis of sources. When the source analyses are examined, IEEE Transactions On Intelligent Transportation Systems (25 publications), Sensors (13 publications), Multimedia Tools and Applications (8 publications), Applied Sciences-Basel (7 publications), IEEE Access (7 publications) stand out as the most influential sources in their fields. Figure 8 shows the data of the top ten sources with the most publications and the highest impact in their fields. A bibliographical examination of the citation analysis of the sources revealed bibliographic matching. Bibliographic matching on sources is defined as the citation of a common work by two independent sources as a result of the citation analysis. While examining the citation analysis of the sources, the criterion of having at least 1 publication and 1 citation was determined and 236 sources that passed the threshold value out of 293 sources were listed. The network map showing the citation analysis of the sources is given in Figure 9. Within the scope of the study, bibliographic matches were also examined for the purpose of source

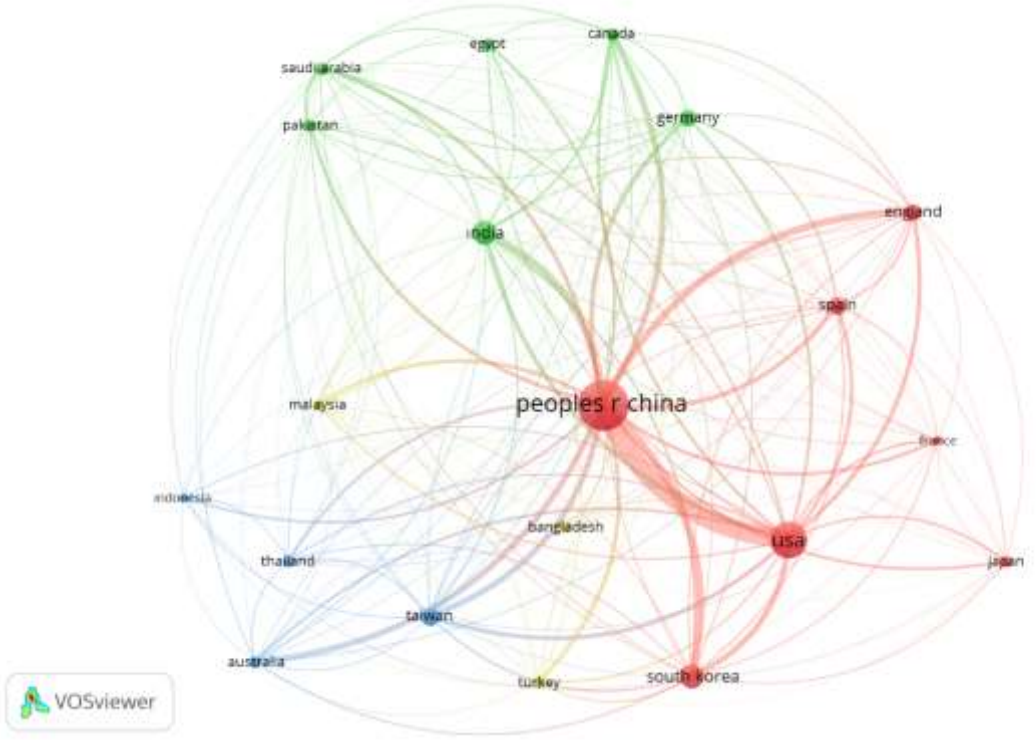

Figure 6. *Network map showing bibliographic matching of countries*

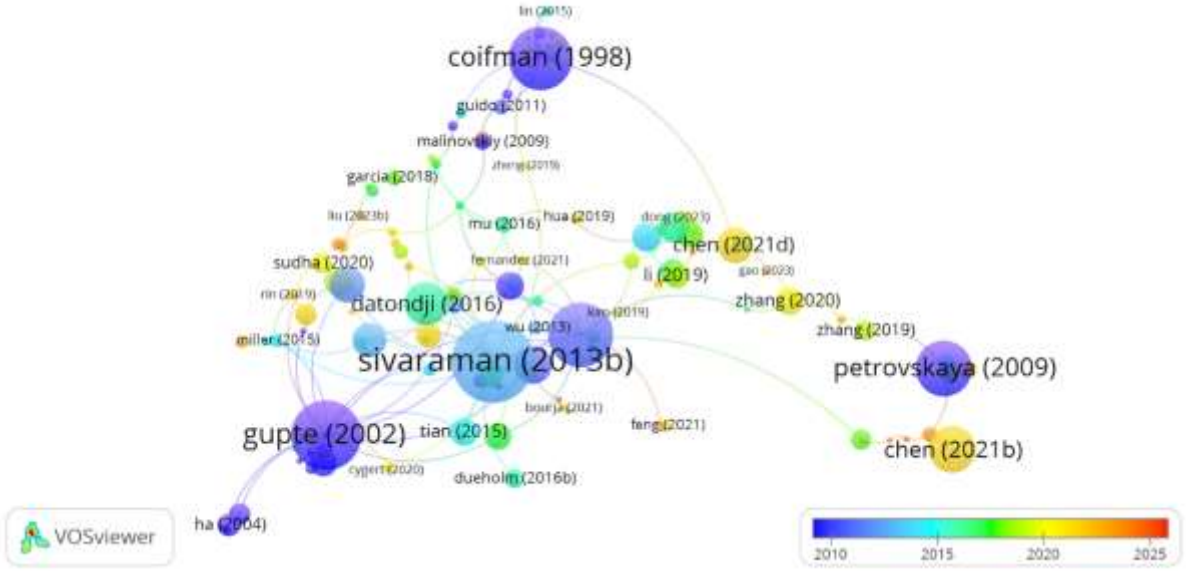

Figure 7. *Authors' citation links*

analysis. It is important to reveal the collaboration between authors who use sources together. Three area graphs showing the analysis between authors and the most frequently used keywords in the sources reveal the bibliographic match structure of the study. Three area graphs revealing the connections between source, author and keyword are presented in Figure 10.

4. Conclusions

The increase in traffic density has led to many studies to solve problems in this area. In order to

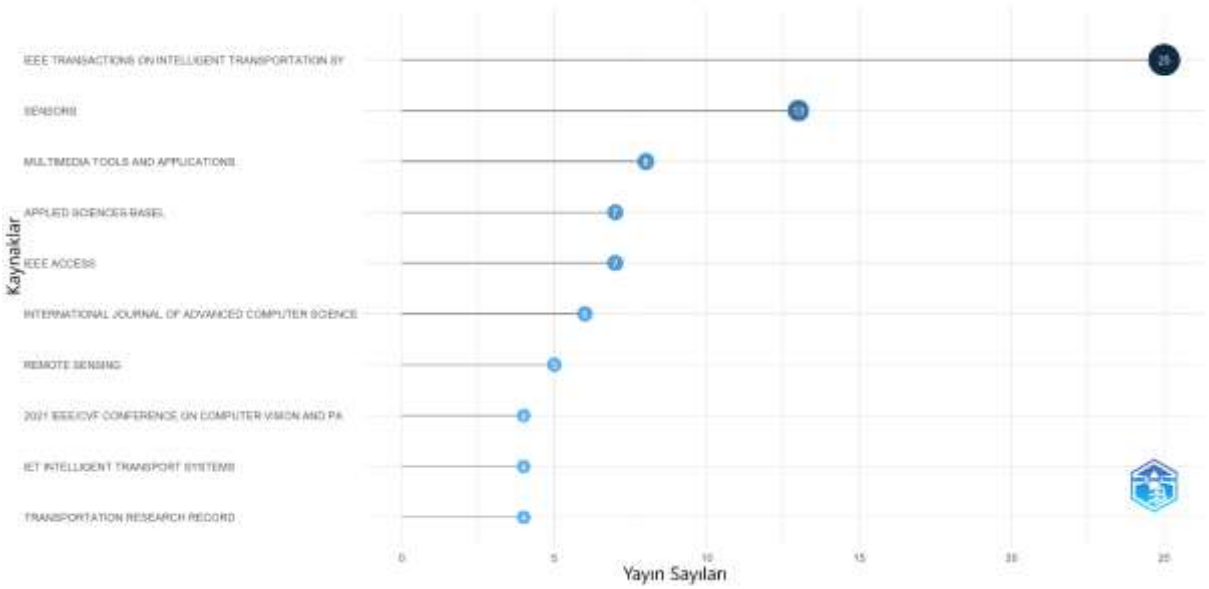

Figure 8. *Network analysis showing the most influential sources and publication numbers in the field.*

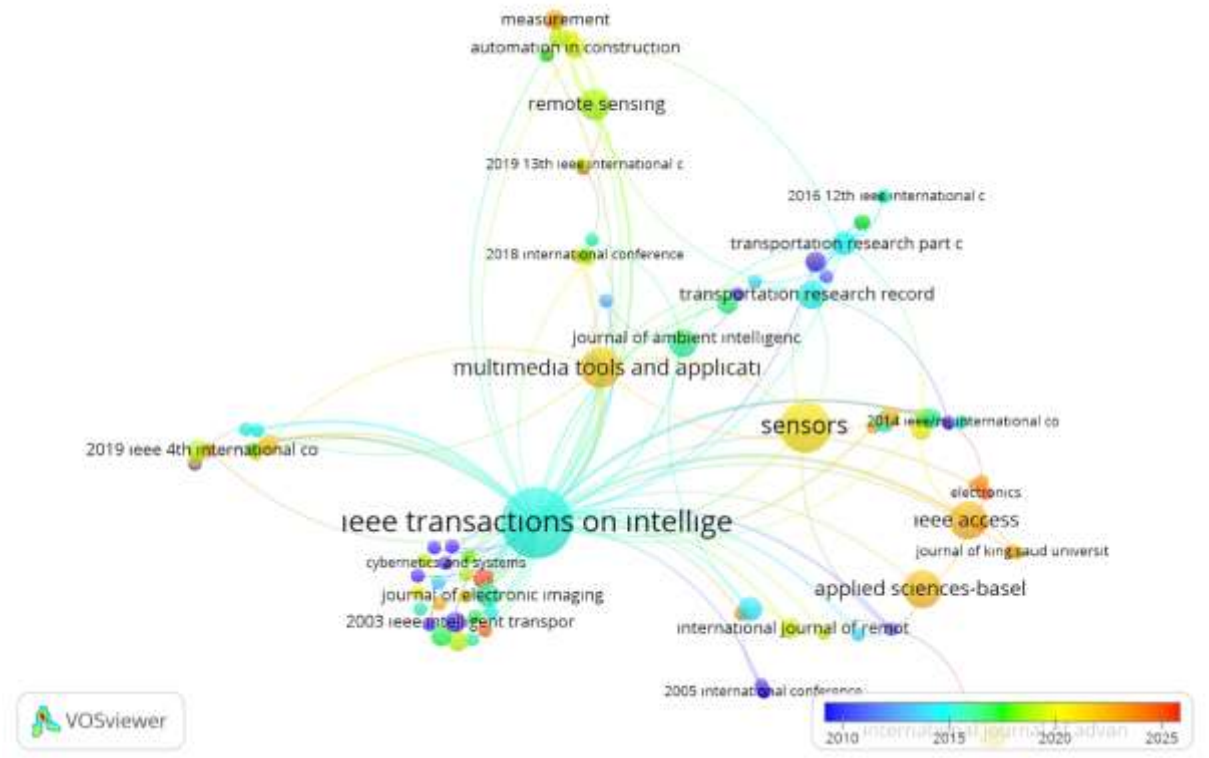

Figure 9. *Citation network map of sources*

prevent many problems through traffic surveillance systems, it has become necessary to conduct analysis on the systems. Vehicle detection and tracking on video images obtained from surveillance systems has become a popular area in recent years. Despite the increase in the number of studies, the desired point has not been reached in this area yet. The aim of this study is to examine the studies conducted on vehicle detection and tracking and to reveal common trends.

The keywords "vehicle detection" and "vehicle tracking" were searched in the Web of Science database using the conjunction "and" and selecting "all fields".

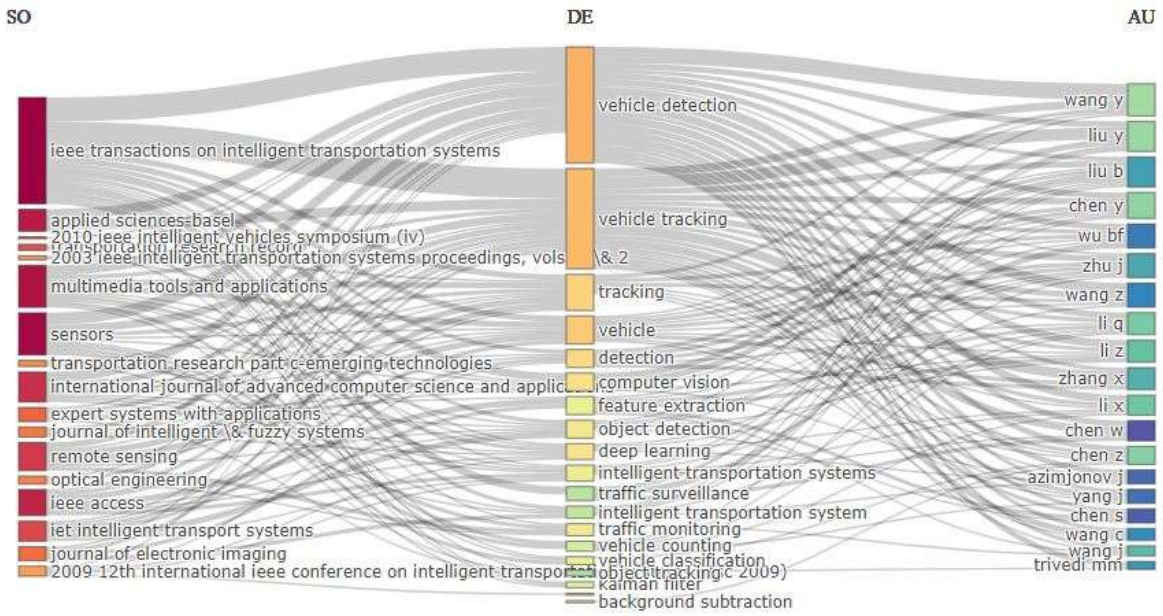

Figure 10. *Three area graphs for source, author and keyword analysis*

A data set was created with 405 publications obtained as a result of this search. The results of the bibliometric analysis conducted according to keywords, authors, countries and citations within the scope of the study are included in the findings section of the study.

The distribution of 405 publications made between 1997 and 2025 by year was examined. It was observed that the publications made in the study area progressed in odd numbers until 2007. It has increased especially after 2013. It was stated that the year 2023 stood out with 36 publications among the publication years. The studies were published in English and Chinese.

It was determined that the most influential authors among 1185 authors were Yue Wang, Yuqiang Liu, Yajun Chen, Zhenzhong Chen, Qingquan Li. According to the keyword analysis, the most frequently used keywords were listed as vehicle tracking, vehicle detection, deep learning, computer vision, object detection.

It was seen that studies were conducted from 53 different countries in the data obtained from the Web of Science database. China, USA, South Korea, India and England were determined as the top five countries. Another criterion taken into consideration when analyzing by country is the number of citations. The countries with the most citations are USA, China, England, Germany, and Spain.

The most used sources in the studies are IEEE Transactions On Intelligent Transportation Systems, Sensors , Multimedia Tools and Applications, Applied Sciences-Basel, IEEE Access and stand out as the most influential sources in the field.

It is thought that the application of the study in the field of vehicle detection and vehicle tracking will guide new researchers who want to analyze video images. In order to increase the effectiveness of the study, bibliometric analysis was applied with the Voswiever (version 1.6.20) program and R Studio programs and the analysis results obtained from both programs are presented. The scope of the study can be expanded to include deep learning algorithms and target tracking on video sequences and thus contribute to the literature. In addition, the study is currently carried out to cover the web of science database. The scope can be expanded by adding data obtained from other prominent databases such as Scopus and Google Scholar in future studies.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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